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Spatial and biocenotic trends in the water-mite fauna of small ponds

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Abstract

Forty-one permanent and temporary ponds have been studied in a mountain range in the center of Spain. Abiotic variables are used to characterize the ponds. Spatial and biocenotic distribution patterns of macroinvertebrates with special reference to the water mite fauna are considered.

Introduction

Temporary and permanent stagnant waters are widely distributed around the world, but temporary waters are the least known, due, in part, to a supposed lack of economic interest. Most studies have dealt with the taxonomy of their inhabitants. For recent, more comprehensive approaches see Hartland-Rowe, 1972 and Wiggins *et al.*, 1980.

Faunal diversity tends to be low, although some of the taxa are quite abundant. Nevertheless, within a restricted area, total faunal diversity is high, due to low repetitivity.

The stagnant waters of the sierra del Guadarrama, a mountain range in the center of Spain, have mainly received a systematic approach. Arévale (1921, 1931) deals with insect larvae and cladocera, Viets (1930) and G.-Valdecasas (1981) with water mites, Alvarez & Selga (1967) with several taxa and Margalef (1947) gives a more ecological view. More recently, we have looked at these ponds from an insular model perspective (G.-Valdecasas *et al.*, 1984).

The present paper tries to understand the spatial and biocenological patterns shown by pond taxa, especially water mites.

[1] Order of authorship determined by the toss of a coin.

Material and methods

Study area

The sierra de Guadarrama is a mountain range in the center of Spain. Its highest point is Peñalara, at 2430 m. The whole area is mainly gneissic. It consists of 5800 km^2, arbitrarily delimited above 1000 m altitude.

The area was divided into quadrats of 5 km per side, and at least one pond was looked for in each quadrat. Out of 115 quadrats only 41 ponds were found (Fig. 1).

Sampling procedure

The sampling period extended from spring into summer, when the temporary nature of the ponds was confirmed.

The following physico-chemical variables were taken at sampling time: altitude, mean depth, surface, water and air temperature (mercury thermometer), pH with Merck indicator paper, hardness (Merck tritiplex), and alkalinity (Aquamerck Alkalinitat). The nature of the substrate and vegetation growths was also noted. Macroinvertebrates were sampled quali- and quantitatively (see G.-Valdecasas *et al.*, 1984). Samples were fixed with formalin in 4% and sorted in the laboratory.

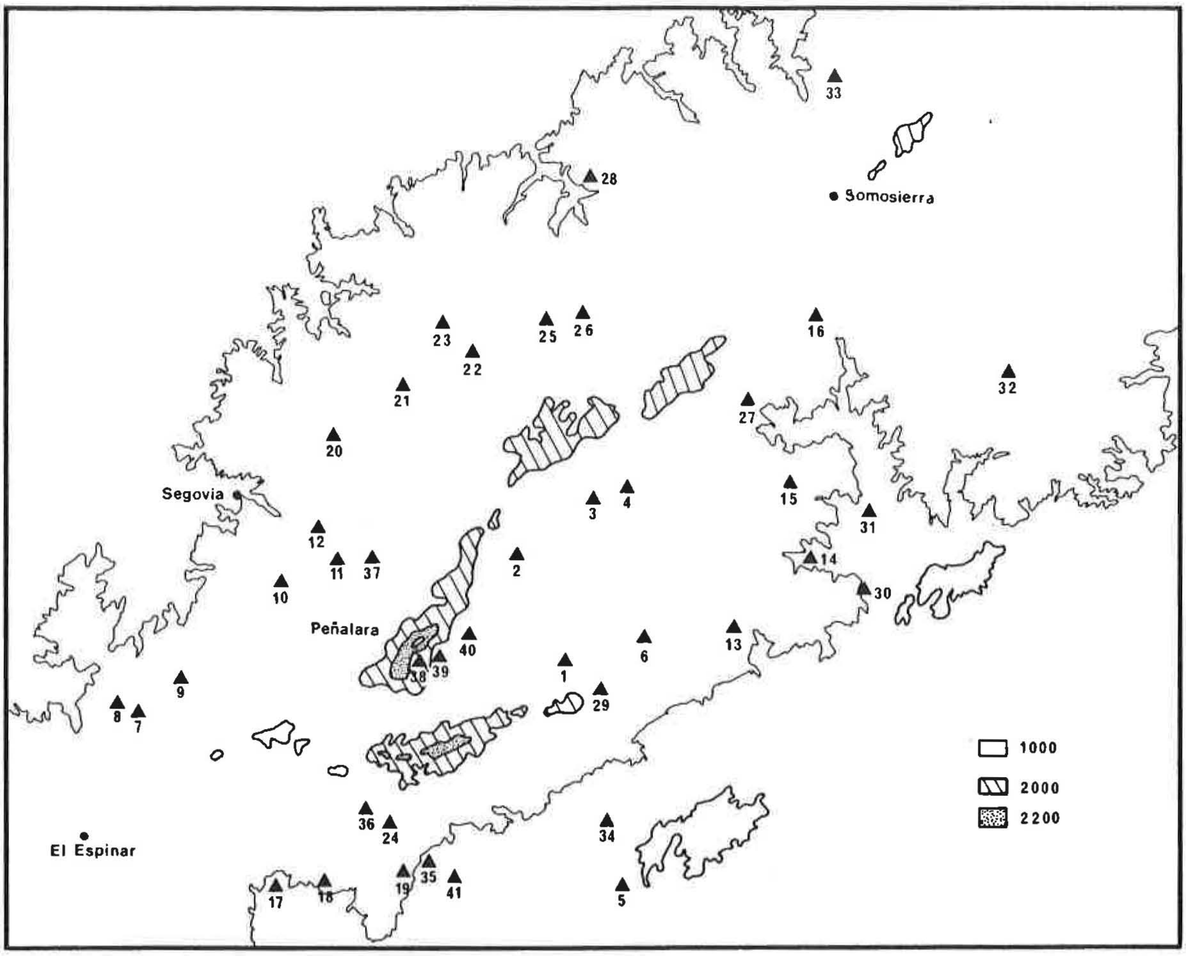


Fig. 1. Distribution of ponds in the Sierra de Guadarrama.

Data analysis

Data analysis was done with the BMDP Computer Package (Dickson, 1983). Programs 1M, 2M and 4M were used for cluster and principal component analysis (P.C.A.). Program 1M used a similarity matrix obtained by applying the Jaccard index to water mite faunal records in ponds. In this case, the average (U.P.G.M.A., see Sneath & Sokal, 1973) was chosen for clustering. In program 2M we selected the Euclidean distance and the centroid algorithm for clustering. Principal components were obtained from the correlation matrix. Analysis of correspondence was done using Lebart & Fenelons (1973) program.

Results

1. Spatial trends

The main purpose of this work has been to investigate the spatial and biocenotic trends in the pond communities of a mountain range. The search for the pattern of spatial directionality was carried out using the Wald-Wolfowitz, non-parametric run test (Siegel, 1956; Wratten & Fry, 1980). Only two spatial directions, North-South and East-West, were analyzed for each of the following cases: the distribution pattern of ponds, water mites, calanoid and cyclopoid copepods and hemiptera, respectively. It was thought that each group would present a different kind of disperson and survival if the ponds dried up. Table 1 shows the values of quadrats, ponds and organisms used for the analysis, where $\bar{X}$ is the mean

Table 1. Spatial distribution trends of ponds and organisms. See text for explanation.

E-W direction

No. quadrat	No. ponds	No. spp. watermites	No. spp. calanoids	No. spp. cyclopoids	No. spp. Hemiptera
4	1	4	0	1	5
6	1	3	0	3	5
9	0	0	0	0	0
10	4	17	8	18	5
12	3	3	3	2	12
13	2	3	1	1	2
12	5	4	2	5	7
11	6	11	9	14	9
11	7	7	8	10	11
10	3	2	2	5	8
9	2	7	0	2	11
8	7	24	5	13	12
	$\bar{X}=0.349$	$\bar{X}=0.974$	$\bar{X}=0.305$	$\bar{X}=0.64$	$\bar{X}=0.805$
	$r=6$	$r=7$	$r=6$	$r=6$	$r=5$
	$n_1=5$	$n_1=5$	$n_1=4$	$n_1=4$	$n_1=8$
	$r_c=3$	$r_c=3$	$r_c=3$	$r_c=3$	$r_c=3$
	$n_2=7$	$n_2=7$	$n_2=8$	$n_2=8$	$n_2=6$

N-S direction

No. quadrat	No. ponds	No. spp. watermites	No. spp. calanoids	No. spp. cyclopoids	No. spp. Hemiptera
4	2	2	2	0	4
4	1	3	3	4	0
8	2	4	6	7	1
10	4	6	4	3	2
10	7	13	4	6	16
11	5	17	3	8	13
11	3	12	5	10	6
12	7	14	6	19	15
10	1	0	0	0	3
9	1	0	0	3	3
9	4	8	3	7	10
6	3	3	0	6	9
4	0	0	0	0	0
3	1	0	0	1	5
	$\bar{X}=0.349$	$\bar{X}=0.618$	$\bar{X}=0.50$	$\bar{X}=0.311$	$\bar{X}=0.772$
	$r=8$	$r=7$	$r=4$	$r=6$	$r=9$
	$n_1=7$	$n_1=6$	$n_1=4$	$n_1=8$	$n_1=7$
	$r_c=3$	$r_c=3$	$r_c=3$	$r_c=3$	$r_c=3$
	$n_2=7$	$n_2=8$	$n_2=10$	$n_2=6$	$n_2=7$

number of ponds or organisms per quadrat, r is the number of runs and n_1 and n_2 the number of + and − signs respectively.

The null hypothesis, which states that the distribution of ponds and organisms in the area of study is random, could not be rejected in any case. That does not mean that random distribution or organisms has really been proved (Pielou, 1969).

This result is reinforced, as we will see below, when the faunal and geographic similarity between ponds is examined. Neighbouring ponds do not necessarily contain similar fauna.

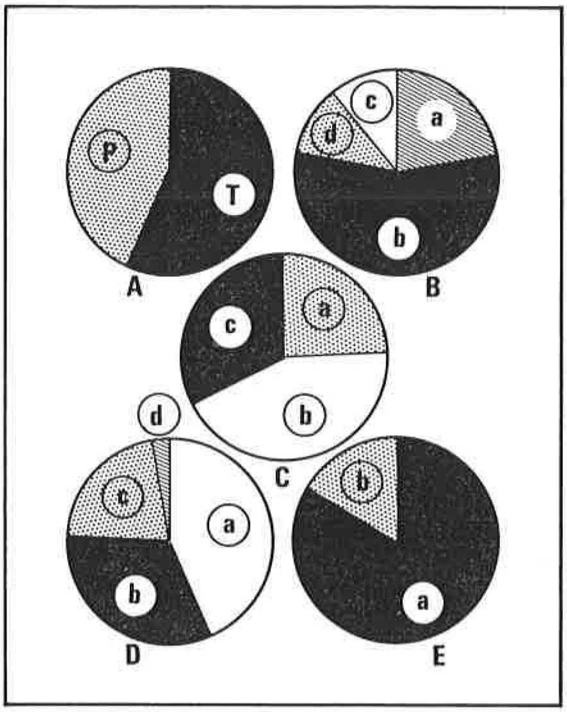


Fig. 2. Proportional contribution of different characteristic for the ponds of the Sierra de Guadarrama.
A- Pond type: Temporal (T) = 56.75%;
Permanent (P) = 43.35%
B- Altitude: 900–1000m. (a) = 21.62%;
1001–1200m. (b) = 56.76%
1201–1600m. (c) = 10.81%;
1601 (d) = 10.81%
C- Alcalinity: 0.15–0.5 (a) = 24.32%;
0.6–1.2 (b) = 43.24%
1.3 (c) = 32.43%
D- Hardness: 0.5–2 mEq/l (a) = 43.24%;
2.1–6 (b) = 32.43%
6.1–9 (c) = 18.91%;
9.1 (d) = 5.4%
E- pH: 5.5–6.5 (a) = 83.78%;
6.6–7.5 (b) = 16.21%

2. Abiotic/Biocenotic trend

First we have analyzed whether there is a clear pattern of distribution of ponds in relation to abiotic variables. Figure 2 and Table 2 synthesize the values of the abiotic variables.

Two different analyses have been performed, one of classification and the other of ordination by P.C.A. Fig. 3 shows the resulting dendogram obtained from clustering with the following abiotic variables: pond surface and depth, hardness, alkalinity, pH, altitude, vegetation and bottom type (this was codified as follows: muddy = 1; stony/muddy = 2; sandy = 3). At an amalgamation distance of 1.2888, 6 cluster groups were obtained. Despite some minor disagreement, these groupings could be explained in terms of the temporary or permanent nature of the ponds. Minor disagreement could be due to the conflicting nature of certain ponds, that, in very dry years, could behave as temporary, and, in wet ones, as permanent ponds.

To clarify this hypothesis, a P.C.A. has been done using the following variables: altitude, area, depth, alkalinity, hardness and pH. Table 3 shows the eigen values, the cumulative proportion of total variance for 6 factors, and contribution of variables to factors 1 and 2. The first two factors explain more than 67% of the total variance. Figure 4 plots the ponds in the coordinated diagram formed by the first two factors. Looking at the contributions of variables to factors, alkalinity, pH and hardness have the highest contribution to factor 1 and depth, area and altitude to factor 2. If we eliminate pH and altitude for their lower variability, the coordinated space could be divided into a fourth area plane, where area I and II correspond to permanent ponds with low and high hardness and alkalinity, respectively. Area III and IV have temporary ponds with low and high hardness and alkalinity, respectively. It seems, then, that abiotic variables define ponds in terms of their temporary or permanent nature, although this pattern is not so well defined as to allow us to make a clear hierarchical classification. Although the extremes, the always permanent and temporary ponds, could be clearly distinguished, between them exists a continuum of alternatively temporary or permanent

Table 2. Principal characteristics of the small water bodies of the Sierra de Guadarrama.

Ponds (number)	U.T.M. (30T)	Altitude (m)	Vegetation	Type	Area (m^2)	Depth (cm)	Alcalinity (mEq/l)	Hardness (°d)	pH
01	V1296215	1740	grass	temporary	480	30	2.9	5.60	6.5
02	VL269293	1150	absent	temporary	280	76	2.9	6.72	6.5
03	V1329335	1120	absent	permanent	280	300	1.5	8.40	6.5
04	VL342343	1120	algae	temporary	34	15	1.5	8.40	6.5
05	VL337058	940	mixture	temporary	140	43	1.4	6.16	6.5
06	VL358227	1280	grass	temporary	30	40	0.5	1.12	6.5
07	UL988191	1180	grass	temporary	4	24	2.6	8.96	7.2
08	UL975192	1160	grass	temporary	9	6	2.0	5.60	6.8
09	VL013208	1140	mixture	permanent	194	43	1.2	1.68	6.5
10	VL091275	1120	algae	permanent	167	30	0.8	1.12	6.4
11	VL132286	1120	grass	temporary	82	27	0.6	1.20	6.4
12	VL121315	1100	grass	temporary	51	42	0.8	3.35	6.5
13	VL425241	1200	algae	permanent	29	16	0.7	2.80	6.5
14	VL484287	970	grass	temporary	27	7	1.0	3.36	6.5
15	V1460346	1160	grass	temporary	19	11	0.3	1.12	6.5
16A	VL486458	1150	grass	temporary	50	25	0.4	0.84	6.5
17	VL081056	980	grass	temporary	74	9	1.8	2.80	6.5
18	VL122056	1040	grass	temporary	16	47	0.7	29.12	6.5
19	VL186068	1000	mixture	permanent	65	31	0.5	1.68	6.5
20	VL141395	1100	mixture	temporary	30	22	0.8	1.68	6.5
21	VL178411	1175	grass	temporary	56	15	0.8	1.12	6.2
22	VL229440	1222	grass	permanent	28	23	1.0	5.04	7.2
23	VL207454	1130	mixture	temporary	148	19	0.4	1.68	6.4
25	VL287463	1200	grass	temporary	182	24	0.6	1.12	6.2
26	VL312465	1190	grass	temporary	600	21	0.4	1.68	6.5
27	VL521381	990	grass	permanent	230	41	1.0	2.24	6.0
28	VL327559	1020	grass	permanent	300	40	1.4	2.24	6.5
32	VL638414	1250	grass	permanent	800	52	0.4	1.12	6.0
33	VL492635	1060	algae	permanent	26	34	5.0	14.00	7.0
34	VL327102	900	grass	temporary	23	6	2.0	8.96	6.9
35	VL197073	990	grass	temporary	13	17	3.2	7.84	7.2
36	VL159111	1325	mixture	permanent	100	15	0.8	2.24	6.4
37	VL159288	1200	absent	permanent	35	44	0.6	2.80	6.4
38	VL195214	2021	absent	permanent	900	900	0.6	1.68	6.1
39	VL208214	1980	grass	permanent	25	20	0.4	1.12	6.0
40	VL221231	1900	grass	permanent	250	16	0.4	0.56	6.0
41	VL213067	950	mixture	permanent	250	400	1.2	2.80	6.5

ponds, that depends more on the climate of the area than the characteristics of the pond.

3. Water mite biocenotic trend

Patterns of ordination and classification of the fauna have been obtained only of water mites, for which extensive data from the sierra already exist (G.-Valdecasas & Camacho, 1986). Table 4 shows pond water mite distribution in the sierra.

Prior to cluster analysis those ponds with only one species and those species found in only one pond were eliminated. Figure 5 shows the dendogram obtained through a similarity matrix. At a 50% similarity level, 6 cluster groups are obtained. If they are analysed with regard to the temporary or permanent nature of the pond, it is found that there is no congruence in any one case. Permanent pond fauna remain in permanent ponds and temporary fauna in temporary ones.

Suspecting that fauna similarity could be due to

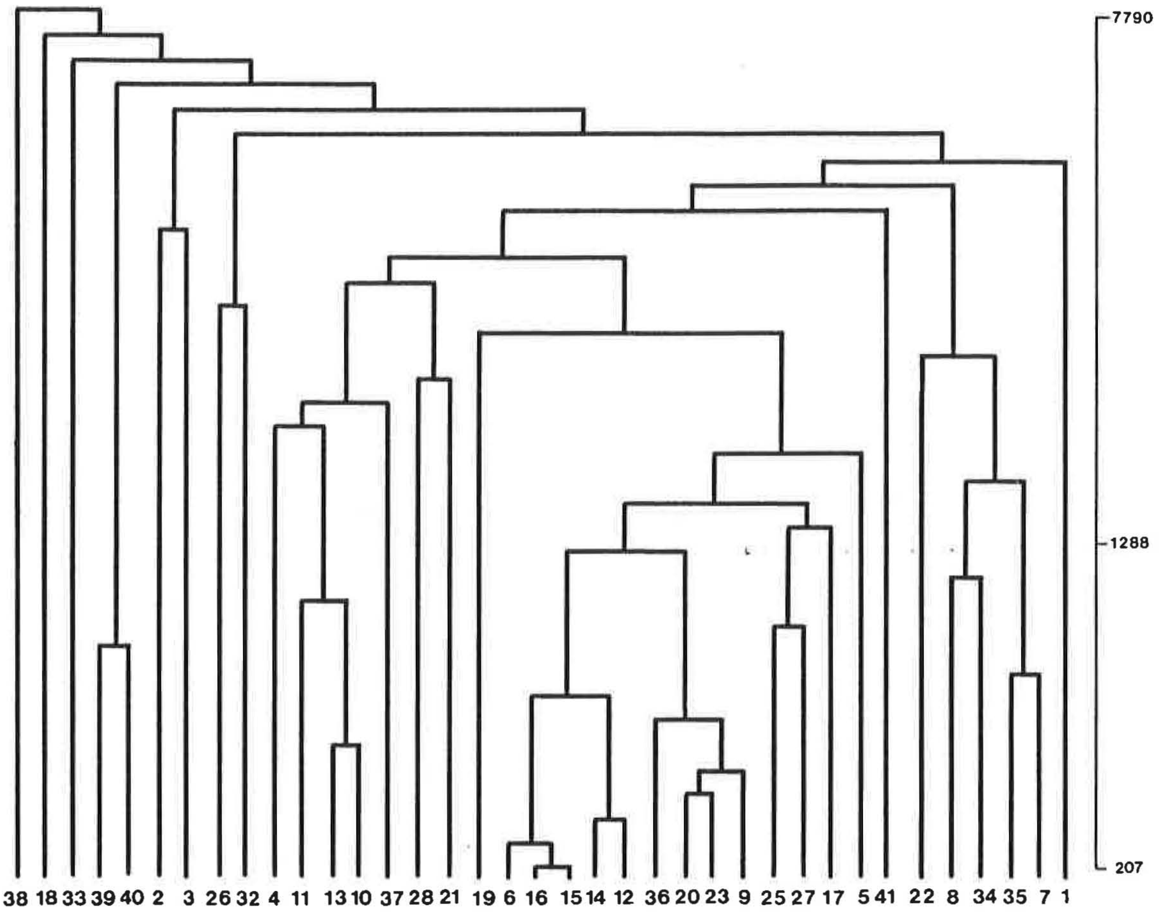


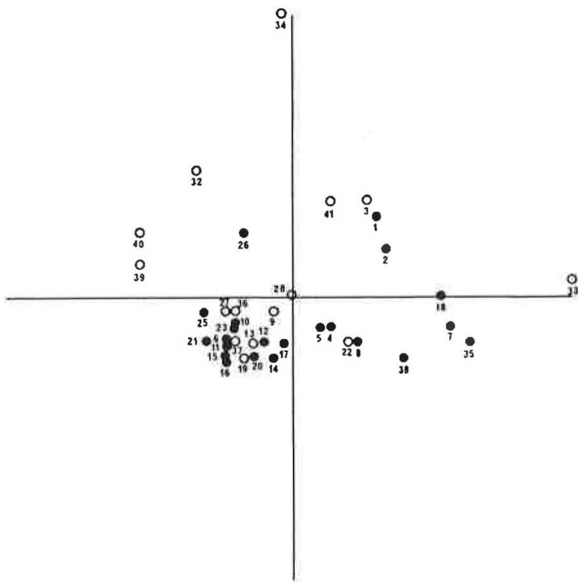
Fig. 3. Hierarchical classification of ponds, based on environmental variables.

the proximity of ponds rather than to their duration, a new classification was done, taking into account geographic locality and coordinates. The classification obtained, that clearly forms groups of neighbouring ponds, does not show any congruence with the previous faunal classification.

In order to take into account, at the same time, species and pond contribution to a multidimension-

Table 3. Eigen values for six factors obtained through a P.C.A.

Factor	Eigen values	Cumulative proportion of total variance
1	2.687957	0.447993
2	1.368274	0.676039
3	0.650225	0.784409
4	0.584381	0.881806
5	0.454958	0.957633
6	0.254205	1.000000



• Temporary
o Permanent

Fig. 4. Two factor projection of ponds based on a P.C.A. of the environmental variables: temporary; permanent.

Table 4. Pond water mite distribution.

	1	2	3	4	5	6	7	8	8 A	9	10	11	12	13	14	15	16	16 B	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Hydrachna globosa																																						X					X
Hydrachna rophaloidea																		X									X																
Eylais extendens					X			X	X		X	X			X		X										X					X	X			X	X						
Eylais tantilla																												X					X										
Eylais hamata					X			X	X			X						X					X				X										X						
Hydryphantes ruber		X																	X			X					X	X								X	X	X					X
Thyas barbigera																			X	X							X											X					X
Euthyas truncata																			X			X						X															
Diplodontus scapularis																																			X								
Hydrodroma despiciens																														X													X
Limnesia koenikei																																			X								X
Hygrobates longipalpis									X																																		
Neumania deltoides																																			X								X
Piona nodata		X		X																		X		X			X																
Piona conglobata										X																																	
Wettina podagrica																																									X		
Tiphys ornatus		X																																									
Tiphys latipes				X													X																										
Pionopsis lutescens		X								X					X						X			X			X	X		X							X						X
Arrenurus ancoriferus																																			X								
Arrenurus distans																																				X	X				X		X
Arrenurus redrogensis																																											X
Arrenurus radiatus																																											X
Arrenurus szalayi																																											X
Arrenurus papillator																												X															
Arrenurus octagonus																																						X					X

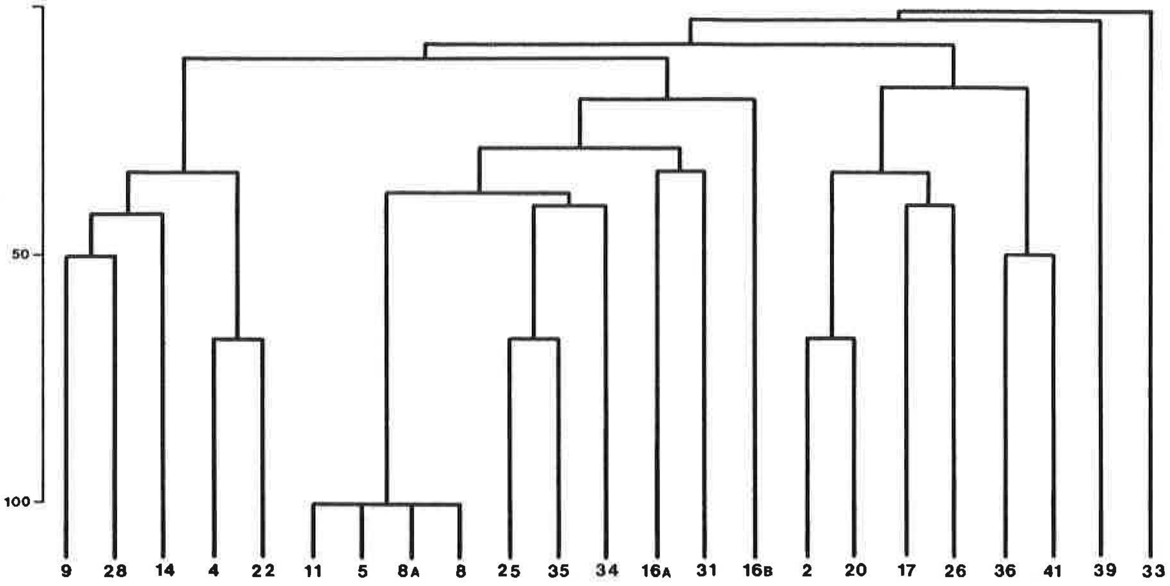


Fig. 5. Hierarchical classification of ponds based on faunal similarity.

Table 5. Ponds and species relative contributions to factor 1 and 2 of the correspondence analysis.

	Factor 1	Factor 2		Factor 1	Factor 2
C02	0.100	0.434	Hydrachna globosa (HYG)	0.278	0.329
C04	0.001	0.078	Hydrachna rophaloidea (HYR)	0.317	0.026
C05	0.742	0.095	Eylais extendens (EYE)	0.705	0.019
C08	0.742	0.095	Eylais hamata (EYH)	0.606	0.014
C09	0.013	0.046	Eylais tantilla (EYT)	0.015	0.077
C10	0.312	0.099	Hydryphantes ruber (HYU)	0.185	0.112
C11	0.742	0.095	Thyas barbigera (THB)	0.167	0.055
C14	0.085	0.011	Euthyas truncata (EUT)	0.042	0.257
C16	0.593	0.012	Diplodontus scapularis (DIS)	0.009	0.036
C17	0.201	0.028	Hydrodroma despiciens (HYD)	0.096	0.062
C18	0.109	0.073	Limnesia koenikei (LIK)	0.088	0.288
C19	0.115	0.067	Hygrobates longipalpis (HYL)	0.012	0.034
C20	0.102	0.333	Neumania deltoides (NED)	0.088	0.288
C21	0.153	0.054	Piona nodata (PIN)	0.001	0.465
C22	0.061	0.341	Piona conglobata (PIC)	0.012	0.034
C25	0.088	0.130	Wettina podagrica (WEP)	0.007	0.009
C26	0.082	0.300	Tiphys ornatus (TIO)	0.001	0.191
C28	0.091	0.005	Tiphys latipes (TIL)	0.163	0.011
C30	0.312	0.099	Pionopsis lutescens (PIL)	0.063	0.234
C31	0.141	0.005	Arrenurus ancoriferus (ARA)	0.009	0.036
C33	0.016	0.122	Arrenurus distans (ARD)	0.109	0.244
C34	0.036	0.000	Arrenurus rodrigensis (ARR)	0.149	0.270
C35	0.062	0.001	Arrenurus radiatus (ART)	0.149	0.270
C36	0.310	0.169	Arrenurus szalayi (ARS)	0.149	0.270
C39	0.028	0.091	Arrenurus papillator (ARP)	0.000	0.190
C41	0.482	0.301	Arrenurus octagonus (ARO)	0.278	0.084

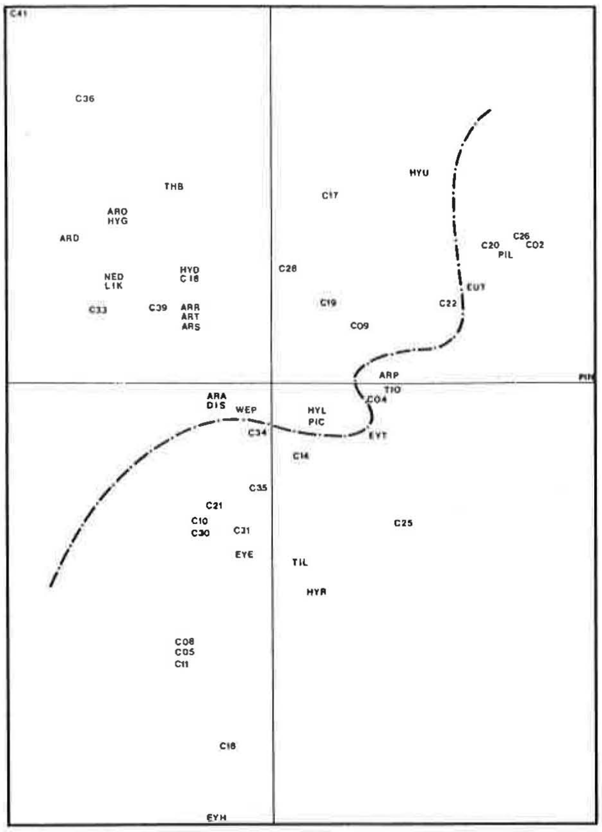


Fig. 6. Two factors projection of the analysis of correspondence between water mite species and ponds. Vertical axis interpreted in terms of the temporary-permanent nature of ponds. Horizontal axis interpreted in terms of the early-late development of water mites.

al, complementary space, we have done a correspondence analysis for the water mite fauna. Table 5 includes the factor contributions for ponds and water mite species. The first three factors account for 46% of the total variance (I = 20.28%; II = 14.62%; III = 12.16%). Figure 6 shows the scatter diagram of the first two factors, and our interpretation of the ordination scheme.

Ponds ordinate in the first factor mainly with respect to their permanent or temporary nature. Those that belong more clearly to one or other of these categories have the highest contribution to this factor. Factor two does not have a clear interpretation in terms of pond ordination.

The species with the highest contribution to factor I are, on the one hand: *Hydrachna rhopaloidea, Arrenurus octagonus* and *Hydrachna globosa* and, at the other extreme, the species of the genus *Eylais: E. extendens* and *E. hamata* predominate. Factor II is strongly influenced at its positive extreme by *Hydrachna globosa, Arrenurus octagonus, Limnesia Koenikei* and *Neumania deltoides.* The highest contributions belong to the negative part of the projected factor, with *Piona nodata, Euthyas truncata* and *Pionopsis lutescens* being the most important species.

A detailed study of species contribution to factors I and II reveals a vertical gradient of temporary versus permanent species, and an early versus late gradient in the horizontal direction. *Eylais extendens* and *E. hamata* predominate in temporary waters but *Hydrachna globosa, H. rophaloidea* and *Arrenurus octagonus* are typical of permanent waters. Those species between *Pionopsis lutescens* and *Piona nodata* and *Hydracna globosa, Arrenurus octagonus, Limnesia koenikei* and *Neumania deltoides* ordinate in an early-late fashion.

On the whole, the early species tend to be present in temporary waters and the gradient moves toward permanent waters where the 'later' species predominate.

Discussion

The irregular distribution of ponds through the area of study, although not completely rejecting the random null hypothesis, does not allow us to accept it. Not every quadrat was searched completely for the total number of ponds they contained. Once a pond was located in a quadrat, the search was stopped, and, unless some other pond in the quadrat was in sight, no more were included. In some areas, the distribution of the ponds studied reflects their accessibility, although not all were near a road or path.

The distribution of organisms in the ponds does not show any definite pattern. Even the proximity of ponds does not assure similarity in their fauna. This fact is a well-recognized one in the literature (Wiggins *et al.*, 1981) of different kinds of organisms. In our case, several factors seem to combine to produce what should be a complex pattern. Even within the same group of organisms, different species have different ways of dispersing and enduring until the next cycle. Some of them survive in the same pond in a resting phase, and some leave the ponds when dry and return when they fill. What complicates the possibility of clarifying this unclear pattern, is that, as has been pointed out by several authors (Williams, 1983; Baltanás, 1985), during its annual cycle, a pond is a succesion of communities; different seasonal samplings for different ponds greatly increase the variability of their species populations at any given time than if compared for a whole annual cycle, and perhaps this could show a more understandable spatial pattern.

In the present state, our findings only strengthen the fact that, apparently, proximal ponds very frequently have a markedly different population.

Analyses of abiotic components have shown the relative independence of the chemical variables from the morphological ones, that is, area, depth and location (altitude). But these last are clearly related to the temporary or permanent nature of the ponds. In an area like the Sierra del Guadarrama, in some years a pond could be filled as late as December, but with snow, although it is more regularly filled by October with the first rains. Only clear extremes will dry up or retain water under very different sets of conditions. More intermediate ponds will shift to the permanent or temporary category, depending on that year's climatic conditions.

Although the physico-chemical variables studied have been few, it seems that only organisms, that can integrate long, enduring patterns in their life strategies, will be useful to discriminate and classify those ponds that in a short sampling period, (which could be a few years!), do not behave in a definite way.

Water mite taxocenosis is an example of this last assertion. One source of variability is the different life patterns. Species living in temporary ponds show two different strategies: overwintering in the dry pool basin mainly as egg or larvae, but in some species with nymphal and adult resistant states, and spring migrants to temporary ponds from permanent ones. Species of the family *Hydryphantidae* (Genus *Hydryphantes, Euthyas* and *Thyas* belong to it), F. *Pionidae* (G. *Piona* and *Tiphys*) and *Arrenuridae* (G. *Arrenuridae*) use the first strategy, and F. *Eylaidae* (G. *Eylais*) and F. *Hydrachnidae* (G. *Hydrachna*) show the second strategy (Wiggins *et al.*, 1980).

Temporary ponds of the Sierra de Guadarrama are typical, autumnal pools, filling in October – November and drying up at the beginning of July. Neither of the two strategies makes any difference to the area under consideration.

What does make a difference is the time of maturity, and this is not necessarily correlated with species strategy but with pond nature. Those species living in temporary ponds tend to be adult early in the year: *Piona nodata, Pionopsis lutescens, Euthyas truncata, Eylais extendens, E. hamata* and *E. tantilla.* Those living in permanent water reach maturity mainly by July-August: *Neumania deltoides, Limnesia koenikei, Hydrachna globosa* and the *Arrenurus* species, excluding *A. papillator.*

Some species can live in temporary or permanent ponds. *Hydryphantes* species that have deutonymph and adult resistant states, depending on weather conditions, could overlap with those species typical of permanent water bodies.

In conclusion, lenthic water mite taxocenosis of the Sierra de Guadarrama clearly segregates, depending on the permanent or temporary nature of their ponds. An early arrival to the adult state is associated with those species living in temporary waters while the eclosion is later for those species living in permanent ponds. The gap between these two categories is filled by those species that are able to survive in both environmental conditions.

Summary

The study of the spatial distribution of the ponds of a mountain range does not show any geographic trend. A similar non-especific pattern is shown by the groups of organisms tested: water mites, calanoid and cyclopoid copepods and hemiptera.

Data analysis of the physico-chemical variables taken from 41 ponds, point to the permanent or temporary nature of the ponds as the most important characteristic, in order to classify them in discrete groups. The same trend is observed when the analysis done is an ordination.

Water mite species distribution in the ponds of the mountain range corroborate this perspective with a clearer pattern: the importance of the permanent versus temporary nature of ponds in relation to their

inhabitant organisms. An early-late trend of adult eclosion is related to pond type. Early species are favoured by temporary ponds and 'later' species by permanent ponds.

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